UTAH'S FLOOD PROBLEM

A Report to

UTAH STATE LAND BOARD

By

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Farmington Spillway ready for receiving 1932 flood stream.

CONTROL OF FLOODS IN MOUNTAIN STREAMS

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Torrential floods, followed by excessive spring freshets, have become a serious menace to the security of life and property in many parts of the State of Utah.

After enjoying many years of prosperous security from this menace, numerous localities, particularly along the Western Front of the Wasatch Range, have experienced during the last decade a series of devastating floods which came without warning, so suddenly as to wipe out the homes and entire household effects of many families, and the lives of several individuals.

In numerous communities where settlement had reached the stage of intensive cultivation of orchard, small fruit and truck crops, and where property holdings were in small tracts of from five to twenty acres, and where comfortable, modern homes had been reared, there remains only a bleak scar of boulders and debris to mark the areas devasted by the torrents of mud, and rocks which spread, without warning from the confinement of canyon walls.

In other localities flooding began soon after the territory was settled, for example the villages of Springdale, Rockville, Grafton, and other small towns along the Rio Virgin below Zions Park, and in Long Valley further up the East Fork were established along a quiet brook with a reasonably abundant area of deep, extremely fertile soil on either bank

of a stream so small that the boys could vault from bank to bank with the aid of a strong pole. Within fifteen years after settlement began floods had taken more than seventy five per cent of the farms, leaving an every spreading channel varying in width from hundreds of feet to hundreds of yards. There seems to be ample evidence to substantiate the conclusion that flooding has been intensified many, many fold, in numerous areas throughout Utah during the eighty-five years of settlement. This being the case it is reasonable to conclude that definite steps should be taken to regulate the various contributing factors over which man has control, such as the management of water sheds and the regulation of timber removal.

Recognizing the seriousness of the situation, Governor Dern in 1930 appointed a special commission charged with the duty of investigating the flood situation in Utah and of bringing to the 1931 Legislature an analysis of the problem with conclusions and recommendations. The commission's report was filed and published as bulletin number 92 of the Utah Experiment Station. As a result of this report and by virtue of Special Legislative Committee investigations a law (Session Laws 1931 Chapter 37) was passed creating or recreating the State Land Board. The new board was particularly charged with the responsibility of investigating the flood situation in Utah and of conducting a survey to ascertain the extent to which floods are likely to occur, in areas where flooding has not been common, determine where flood control structures need to be built, purchase, or when necessary condem rights of way, and stimulate activity on the part of local communities, and other interested parties, to the point of establishment of definite programs of organization, prevention, and control.

In carrying out this special assignment, the board sought the cooperation of State and National agencies who were already in the field working in a limited way, upon the problems in question. Those brought into service include the State Experiment Station. The National Forest Service, and the Bureau of Agricultural Engineering United States Department of Agriculture.

The investigations were divided into two phases, one dealing with the study of water sheds, the other with questions of control of floods to prevent, as far as possible, further destruction of life and property and to provide a suitable organization for building flood control works and for keeping the same in shape for effective operation.

Flood Control Investigations

Intensive studies of the flood control problem began in Utah in 1922, following a series of floods at Spring City, and in Salt Creek at Nephi. These investigations were conducted by the Bureau of Agricultural Engineering, U. S. Department of Agriculture in cooperation with the State Experiment Station, the State Extension Service, and the water-users in the localities where work was undertaken.

Later the State Road Commission, the Railroads and Interurban Lines, and the counties and flood relief organizations in the several localities where floods became prevelent, joined in the cooperative movement with the result that structures of a substantial character have been reared in numerous localities throughout the State.

In approaching the question of control the State Land Board has drawn into service the machinery already in operation, with the result that all the forces at work on the problem are now martialed under one leader.

In this way the limited funds available for assisting in the actual work of building control structures, have been used to advanatage in supplementing the labor supplied locally. In many cases a very limited amount of assistance from public funds has been the means of stimulating local activity to the point of accomplishing tasks which seemed to be an utter impossibility if left entirely to local initiative.

STATUS OF DEVELOPMENTS IN FLOOD CONTROL

Taking into account everything accomplished through cooperative effort by way of placing flood streams under partial or complete control in the State of Utah, structures have been built as follows:

A- Permanent diversion dams for irrigation systems, to replace temporary structures washed out every year by floods:

One on Shoal Creek at Enterprise
" " Canal Creek at Spring City
" " Haights Creek at Kaysville
" " Willow Creek at Willard
" " Escalante Creek at Potato Valley
" " Salt Creek at Nephi
" " North Creek at Beaver

B- Flood barriers and spillway structures for flood protection and to hold back gravel carried by high water:

Two structures on Salt Creek at Nephi
One on Corn Creek at Kanosh
" " Chalk Creek at Fillmore
" " Summit Creek at Santaquin
" " Summit Creek at Summit
" " Parowan Creek at Parowan
" " Willow Creek at Willard
" " North Cottonwood Creek at Farmington
" " Pleasant Creek at Mt. Pleasant

Two on Payson Creek at Payson
One on Parrish Creek at Centerville
" " Barnard Creek at North Centerville
" " Three Mile Creek at Perry

One on North Willard Creek at North Willard
" " Davis Creek at South Farmington, Spillway not yet finished.

C- Flood Barriers under construction:

One on Steed Creek at Farmington
Three structures on Dry Creek, Bountiful
One on Ford Creek at North Centerville
Three on Little Valley Wash at Magna

D- Equalizing Reservoirs:

One on Shoal Creek at Enterprise
" " Summit Creek at Summit
" " Parcel Creek at Glenwood
" " Woodruff Creek at Woodruff

Invariably the damage from floods to homes and lands is a result of the debris carried rather than the excessive flow of water. When the burden of mud, rocks, and rubbish has been removed, the flood channels will usually handle the water without difficulty. The success of an undertaking to control a floodstream is, therefore, dependent upon the provision for equitably relieving the stream of its load of debris. This has been accomplished most effectively by providing areas at or near the mouths of canyons where the streams may spread over relatively broad, uniform surfaces. In this simple fashion the velocity of the current is checked which operation alone is sufficient to cause the stream to drop its load.

When cleared of its burden, the water is collected above a cross barrier, and passed over a spillway into the natural channel. Provision must be made to prevent the stream from spreading beyond certain limits in cases where a natural site is not available. This is accomplished by constructing lateral embankments on either side of the spreading area to keep the flood stream within bounds. This system

has been successful, and economical even where it was necessary to locate the debris barrier on the very crest of the flood plane below the confinement of natural marginal embankments provided by canyon walls.

In every instance, the barrier method of control has succeeded not only in holding back the sand and gravel carried by spring freshets caused by melting snows, but also in checking and unloading the floods caused by torrential storms. Most of the structures have been put to severe tests and there has not been a failure.

Debris Barriers Economical in Construction

As an example of economy, the two barriers on Salt Creek erected in 1922 and completed in 1923 cost the Nephi Irrigation Company $3300 most of which was paid in labor. There has been no further expense and the structures have completely controlled the floods of spring and summer which were formerly a serious menace. In 1922 the company had spent $4800 for cleaning debris from canals and laterals which expense in a single season, amounted to $1500 more than the total cost of building the control barriers.

One of the more difficult situations to handle was presented at Willard where the flood of boulders and mud completely filled the old channel which in places had been 50 feet deep, and left a ridge of boulders, at least 6 feet above the natural surface on the side toward the main part of the town.

The scar left by the flood was selected as the site for the debris barrier, even though the ground surface was already higher than the natural land on either side. There were no lateral embankments, and

nothing but boulders with which to build them. During construction there followed a constant struggle to hold the spring floods within bounds, until materials were washed into place with which to raise the embankment on the side toward town to a height, sufficient to overcome the tendency to overflow. In this instance the relative cost has been much higher than at Nephi but it has been justified by the fact that the floods have been kept within bounds, constantly, and have been prevented from devastating four or five city blocks of homes and from blocking each spring and every summer the only through highway to the North, as well as two railroads. The immense deposits of debris held within the embankments would normally have spread over highly improved farm lands as well as city streets, gardens and orchards, rendering the same virtually valueless, to say nothing of the necessity of abandoning many homes now occupied in comparative security. The expense for control has been distributed among and born by the numerous interests involved, the contribution from each being so small as to be inconsequential when benefits are taken into account. Equalizing reservoirs as built serve a double purpose. They not only check the flood stream, thus reducing or eliminating its damaging effect, but also make it possible to utilize the water held back for irrigation purposes. In the case of high water freshets, the flood stream is equalized so that a flow of uniform volume may be delivered for irrigation. This is of marked advantage in securing maxium use of a limited water supply.

Utah's Flood Problem Analyzed

In mapping out a comprehensive flood prevention and control program for Utah, it is recognized that water-shed management is of prime importance and must receive the attention warranted in order

that the control works may be of lasting benefit. There are, however, certain areas where preventive measures can never become economically effective in eliminating torrential floods. In such cases nature may already have reached a balance between precipitation, natural water-shed cover, and erosion; and the problem of flood control may be confined to a consideration of the effects of floods upon man-made improvements on and adjacent to the main stream channel in its lower reaches, such as is the case with much of the Colorado River Basin. It is not intended that this report shall go further than recognize such a situation but that it shall cover principally the problems involving areas under water-sheds where a physiographical balance not been reached, and where life and property are at stake because of the rapid physical change in progress due to unusual flood action.

Observations and detailed studies which have covered the major part of the State indicate that there are many streams where attention to flood control is required if serious damage and loss of property, and possibly loss of life is to be avoided. In some cases, severe floods have not yet occured since settlement of the area began; but by comparing water-shed conditions with similar areas where floods have occurred within recent years, it is logical to conclude that the way has been prepared for catastrophy in many additional localities unless preventive measures can be made effective before heavy storms concentrate over certain watersheds. This problem is reported in

detail by the cooperative agencies responsible for this phase of the investigation.

In many other sections floods have already occured, and effective control works have not yet been installed.

A partial list of streams or localities where control works are needed, or where detailed studies should be made is outlines as follows:

1- Oquirrh, where the entire town is in jeopardy and where a very simple barrier and spillway will be the means of preventing disaster, which will accompany a heavy flood.

2- Mercur, where roads leading to the settlement are made impassible by every flood.

3- Eureka, where floods threaten the security of both residence and business districts. This problem requires special study.

4- Hommonsville Canyon, between Eureka and Elberta, where the State Highway and sections of railroad are in jeopardy

5- Goshen, Slope above Alberta - Detailed study necessary in order to outline type of works which will be most effective.

6- Snowslide Gulch in Provo Canyon, The State Highway is menaced.

7- Rock Gulch at Springville. This involves the security of the entire investment of the State Hatchery and wild game establishment, as well as the property holding of the community.

8- Big Cottonwood Canyon near Salt Lake, where the highway and city water works are involved.

9- Price River and tributaries including:

A-Willow Creek
B-White River
C-Gordon Creek

10- Flood Hollow at Glenwood, which is a menace to a large part of the settlement.

11- Salina Canyon, affecting a portion of the town the railroad, the State Highway, and a large area of farming land.

12- Peterson Hollow, near sigurd.

13- Kanab Creek, where the water supply for irrigation and portions of the town, the farming area and the highway and railroad are involved.

14- Virgin River through Long Valley, where the limited areas of farm lands are washing away, and where State highway interests are at stake.

15- Johnson's wash, near Kanab.

16- Antimony, where the entire settlement in 1932 was damaged.

17- Hurricane, involving a difficuly problem including the canal system, and protection against flooding much of the town.

18- Santa Clara Creek, near Santa Clara, where an equalizing reservoir is needed, and where protections against loss of farm lands are problems to be worked out.

19- Shoal Creek, near Enterprise, where further control works are required.

20- Kanarrah, where an equalizing reservoir will save much destruction of property, and add materially to the effective use of a limited water supply.

21- Coal Creek at Cedar City, here the entire town is menaced by the probability of excessive flood.

22- Red Creek at Paragoonah, requires protection of the irrigation system.

23- Beaver River at Beaver, where damage has not yet been serious and where protection may readily be provided.

24- Meadow Creek at Meadow, where irrigation works are in constant jeopardy.

25- Oak Creek at Oak City, where both town and farms are menaced.

26- Black Creek and Mill Creek near Moab, not yet examined in detail.

These and many more small streams are subject to flood whenever storms with average concentration strike the water sheds. In many cases preventive measures may be effective in guarding against disaster if steps in the right direction are taken in time. In other cases control works are required for adequate protection even though a systematic effort is made to prevent the

development of floods. As a rule it will be necessary to maintain structures in a good state of repair in order to prevent unnecessary damage, even though water-sheds may be managed with high state of efficiency and in a way intended to provide ultimate prevention of floods.

Streams which have been subject to heavy flooding for several seasons, where deep channels and rivulets have been eroded through a loose soil cover, will require protection against flood damage for a long time regardless of efforts at prevention. For these reasons it is recommended that a consistent program of flood control be inaugurated and continued until every stream, which is subject to flood or which may reasonably be expected to develop devastating floods, shall be placed under control as far as conditions will justify.

In an effort to stimulate activity the Board has provided limited assistance to a few communities in the purchase of materials needed for construction, where it was clearly evident that, without such help, the local people would not have the courage to undertake the task of providing protection against further disaster. These materials, and the special services required, were administered by the engineer from the Bureau of Agricultural Engineering, under whose leadership the flood control works thus far undertaken, have been built. Furthermore, a liberal supply of additional materials have been secured, and are available for distribution as soon as weather conditions will permit the continuation of work in the field.

It is found that this method of approach to the problem brings exceptional results. In every case thus far, the property owners are ready and eager to work. They require only the necessary leadership to outline

methods of procedure, and in most cases, a little help to cover a very limited cash outlay, in order to accomplish the tasks of providing flood control, which, at first seem to be impossible of attainment, under existing conditions.

It is imperative that this type of service be provided from public sources if the desired results are to be accomplished. Enough has been done to demonstrate the feasibility of the undertaking.

Seriousness of Flood Problem

Indicated by analysis of cost in Maintaining State Roads.

A few figures obtained through the courtesy of the State Roads Department, serves to indicate the immensity of the flood problem in Utah. The expense in maintaining state roads is only a fraction of the total loss to the state due to torrential floods.

One of the districts where loss has been heaviest in recent years is the Davis County strip between Salt Lake and Farmington. In addition to regular maintenance expenses, there has been spent for clearing flood debris from the highway between North Salt Lake and Farmington the sum of $72000 since 1924. This does not include the heavy outlay caused by the devastating floods of 1923 figures for which are not available.

In 1930 the total expenditure on roads in cleaning up flood debris and making repairs due to floods amounts to $145,295.03., and in 1932 it amounted to $75,558.84.

Repetitions of these heavy expenditures can be prevented by promoting a cooperative plan of control, to the point of providing adequate structures where control is required.

Ultimately the program must include a comprehensive plan of flood prevention as soon as state and local resources will make such an undertaking possible, but in the meantime the worst situations may be handled in a manner such as to prevent further serious damage, by carrying through to a conclusion the type of control program which has been successfully inaugurated on the streams to which reference has been made in this report. Such a plan calls for close cooperation on the part of all interests to be benefited and can be successfully initated by maintaining the organization already set up and in operation through the State Land Board. Therefore it seems consistent and logical to conclude that the work of stimulating local activity, and of providing limited help where necessary should be continued until the State of Utah is made safe against disaster from preventable devastation due to the action of Torrential floods and the flows of and and gravel which inevitable follow during flushes of high water.

Erosion North Salt Lake, 1952.

Erosion West of Salt Lake on
North point of Oquirrh Mountains

Erosion of foot hills near Bountiful, showing goat herd which grazes over the Bountiful Water-shed.

Near the crest of the Davis County water-shed, where floods originate.

Scenes Along Main Street, Willard, following the flood of August 15, 1925.

Looking down Main Street Willard, from the north end of town, August 18, 1923.

This barn, c ontaining livestock, Automobile trucks, and 75 tons of hay was carried 1/4 mile and deposited on Main Street.

Site of the Willard Flood Barrier
September 3, 1923.

The same May 10, 1924, two days after
construction began.

In 1925 the Willard Barrier Basin was extended 500 feet further south along the State Highway. This picture shows the interior of the south west corner as it was prepared to receive the 1925 deposit of gravel carried by high water in May.

This Panoram shows the same view in July 1926. following a summer freshet, after gravel deposited in May had been scraped to the outer bank.

Willard Barrier at the close of the second high water season following control,(June 1926)

A close up of the spillway, same date.

Interior of the New Barrier Basin - June 1925.

Raising the outer bank still higher- July 1926, Just previous to summer flood, see Panoram on previous page.

Closing an opening through one of the control deflectors at upper end of Willard Barrier Basin.

South West Corner of Willard Barrier, July 30, 1925, during the second season of operation.

Timber coarse straw and boulders, were used to define the limits of the Willard Barrier Basin.

Another view of the Barrier during the first few days of construction. The natural slope of the ground surface was away from rather than toward the channel excavated by steam shovel through the flood debris. When the flood was allowed to spread at random over the depository there followed a constant battle to prevent it from over-topping the lateral embankment, beyond which it would have flooded homes and orchard lands.

A Beaver dam built by man to divert the stream (Willard Creek) into the Barrier Basin.

Temporary spillway just above highway crossing.

Drifting gravel becomes a menace following torrential floods. In an effort to cope with the problem, the State highway department in cooperation with the Willard Flood Relief Committee excavated a deep, narrow channel from the mouth of the canyon to the low lands, across the highway and both railroads a distance of over a mile. It had been assumed that by confining the stream in this manner its high velocity would carry the burden of sand and gravel along. On the contrary, however, the new channel was filled to bank level with gravel within 5 days after high water began to flow. Highway and Railroads were blocked and valuable farm lands were buried beneath a heavy bed of gravel. Photograph shows emergency crossing at highway, and teams at work endeavoring to keep the channel open, on the day flood control work began May 8, 1924.

The same 5 days later. When the stream was cleared of its burden, above the hastily improvised barrier, it was free to pick up a new load. Note the successive erosions caused by daily fluctuation in runoff from melting snows. The channel was deepened 18 inches the first night after control, 12 inches the second night during the peak of heavy runoff and so on until a permanent bed was reached 12 feet below highway level.

Railroad Crossing at Willard Creek - 2 days after stream was placed under control.

Crib and rock protection in Willard Canyon, beneath a 75 foot bank of gravel.

Farmington Flood Barrier in its early stages of development.

The same after successfully controlling a heavy torrential flood on July 3, 1925.

Farmington Spillway following a torrential flood.

Debris deposited above the Farmington Barrier by the flood of July 3, 1926. Control was so complete that the citizens did not know a flood was on. Without control there would have been a repetition of Aug. 13, 1923.

Farmington Spillway at first stage of development.

The same during spring runoff in 1925.

Two views showing details in early construction of Farmington Barrier and Spillway -- Embankment was hauled into place by team at a cost of 25 cents per cubic yard.

Farmington Spillway of Rubble-Concrete during the first season of operation April 1925.

The same in 1927.

Farmington Flood Barrier at the close of a season of excessive high water which carried hundreds of thousands of cubic yards of sand and gravel into the control basin.

Looking up stream from spillway into Farmington Barrier Basin.

Ford Creek, Davis County, after the third torrential flood in recent years. The high banks of sand and gravel were deposited when Lake Bonneville occupied the higher levels. These banks are characteristic of each of the Davis County flood channels. It has been proved conclusively that the recent floods have cut through these Bonneville deposits for the first time since the lake receeded over 25000 years ago.

Result of mud flow from torrential flood, Ford Creek August 13, 1923.

The disaster of 1923 repeated on Ford Creek in a series of three floods in 1930.

Ford Creek in 1924 following 1923 flood. Looking down stream across highway on which great quantities of gravel were deposited during spring runoff. It is characteristic that heavy gravel flows follow excessive torrential floods.

Looking across State highway at Ford Creek following 1930 flood. - Note depth of flow and size of boulders compared with automobile in foreground at left.

Parrish Creek showing Centerville school in the midst of an area devastated by the floods of 1930.

Remnants of a home on Parrish Creek near the Centerville school, September 1930.

Highway below Centerville School, Parrish Creek
1930 floods.

Another home near Centerville School, 1930.

Two pictures showing consistency of mud flows in Davis County floods. This accounts for the ability of such floods to carry boulders weighing more than 200 tons each far out on to flood planes below the confinement of canyon walls.

Bingham was also severly hit by flood and fire.

Weber Canyon, Aug. 1930. Looking down stream where torrential flood carried a dam completely across the River, forcing the stream to flow down the highway.

Digging the State Highway out after a typical Davis County flood.

A minor flood from Steed Creek blocked the highway as indicated.

Highway of Steed Creek crossing during torrential flood, looking up stream. Autos are in outer edge of flood and are partly buried.

A woven wire fence parallel to direction of flow held a torrential flood within bounds, just above highway crossing at Fiddlers Creek, near Cedar City.

Looking up stream across Salt Creek upper Barrier after it had been in operation two years. Note the immense deposit of gravel above the water line also the extent of the still water pool which did not fill during the first twenty four hours as was predicted by a skeptical water user.

Spillway through above barrier.

Lower Barrier on Salt Creek above Nephi at the beginning of the third season of operation.

Salt Creek out of bounds at Plaster Mill above Nephi, on the evening of Aug. 13, 1923 the same time that Farmington and Willard were devastated.

Chalk Creek before control in 1921 - Note that stream bed is filled above level of adjacent farms.

Chalk Creek Barrier and Spillway which for ten years has successfully controlled floods and caused the high water streams to completely unload their burden of gravel which was formerly a menace to successful irrigation.

Chalk Creek during spring runoff in 1921, before control.

Chalk Creek above Barrier in 1923, after a season of heavy runoff.

Kanosh Creek - Barrier and Spillway soon after completion Note the depth at lower toe. Also the cutoff structures in foreground at right; same to prevent erosion. Crest and floor of Juniper timber, wings of cottonwood and boulders.

The same after two seasons of heavy use, Note deposit of silt at the lower toe of spillway, showing effectivness of downstream cutoff.

Sand and gravel were a serious menace to Parowan City and to the irrigation system before the Barrier was built in 1925.

Gravel deposited above the Parowan Flood Barrier supplies the building needs of the community.

Parowan Barrier after a terrific summer flood. Fine debris carried down to crest of Spillway but no coarse material even approached the structure.

Parowan Barrier Spillway - Note expansion of wings to accomodate excessive floods.

Excavation for Shoal Creek Diversion Dam, above Enterprise.

The same after Dam was finally completed.

Looking up stream through spillway of Shoal Creek Diversion Dam.

The same looking down stream. This structure made of Juniper timbers cribbed and spiked together and loaded down with dirt and rocks puddled into place.

Equalizing Reservoir No. 1 - on Shoal Creek

Equalizing Reservoir No. 2 on Shoal Creek. These Reservoirs built by Water Users with but little skilled help.

Constructing Flood Control Diversion Dam at Summit

The same after completion and after a terrific summer flood carrying boulders weighing tons each.

Diversion Dam above Orderville
This structure crude as it is, has been a material factor in preventing excessive erosion of the upper Virgin immediately above Orderville.

Diversion Dam above Escalante in Potato Valley.

Diversion Dam on Canal Creek, after a terrific flood in July 1922.

Diversion Dam on Haghts Creek, buried by a devastating flood July 3, 1926 - When uncovered the structure was found to be intact except for one wing.

Mt. Pleasant Flood Barrier Spillway - Nearing completion November 11, 1928 - Looking downstream.

The same in September 1929 following a terrific mud and boulder flow looking up stream.

Manti Barrier
At the close of the high water season.

Manti Barrier Spillway in operation. A close up.

Constructing the main barrier and spillway in Payson Creek, rocks dragged into place by teams are grouted with concrete to hold them in position.

A secondary spillway on Payson Creek made of timber Photograph shows main floor being placed.

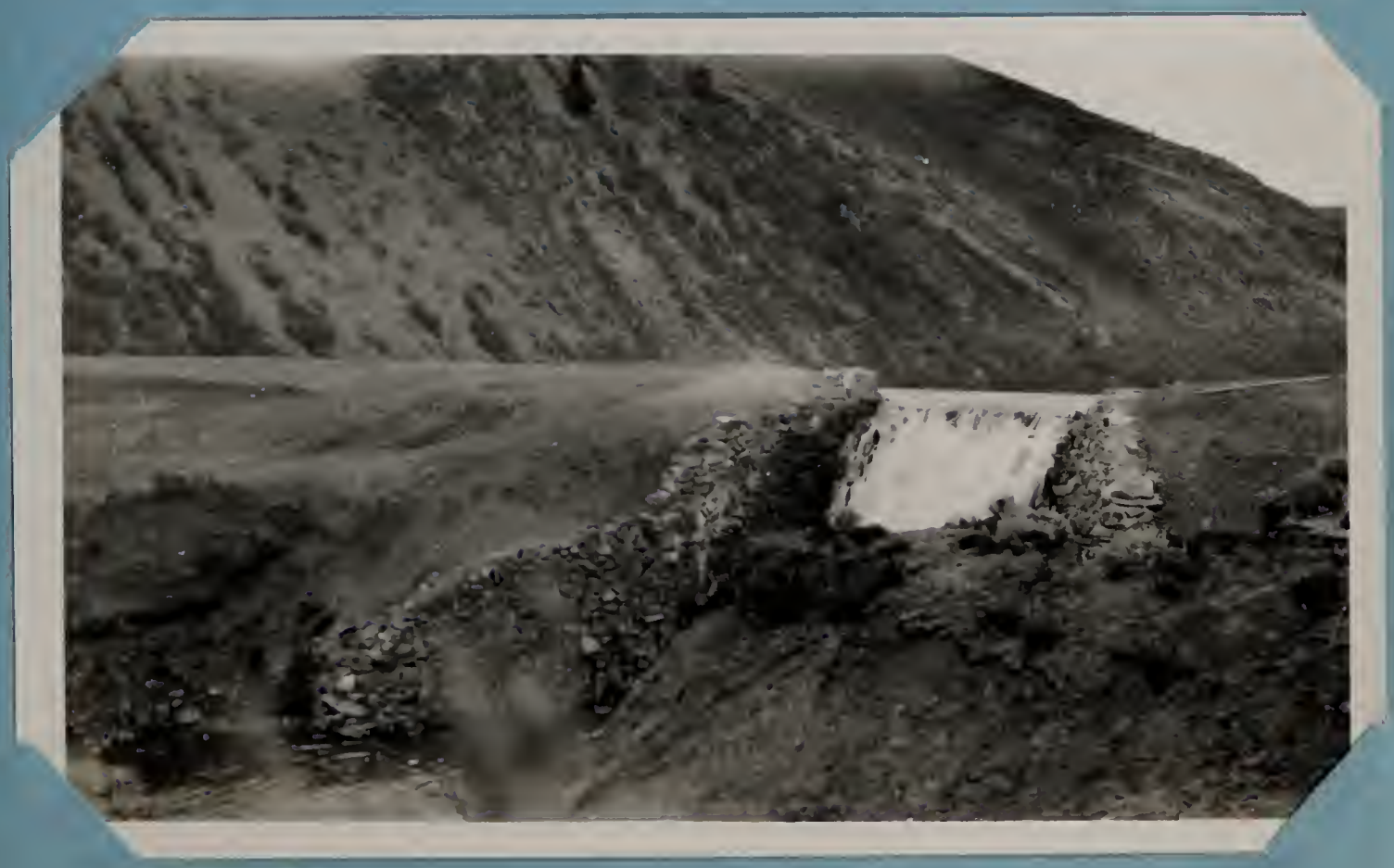
Erosion on Santa Clara Creek is a problem of great concern to the farmers of St. George and Santa Clara. Note the depth of the fertile orchard lands. The last flood widened the channel over a hundred feet at the point shown.

An attempt at control on Santa Clara Creek. The water users are willing and anxious to do what they can to save their farms. Since this report was written they have been organized for flood control and are at work under an assistant to the author who is carrying out an organized plan of control along the entire stream.

Woodruff equalizing reservoir, showing first construction camp, 1926, and beginning of the new dam. This structure is being raised at the rate of six to eight feet each fall. The spillway is a part of the dam and is made of rubble-concrete.

Woodruff Spillway at the height of 24 ft. which was the first level reached.

Woodruff Reservoir spring of 1930, during the time of heaviest spring floods.



Woodruff Spillway - 1930

Kessler Canyon Barrier Spillway - looking down stream toward Garfield Smelter. This structure stands 80 feet above original stream bed.

The same after a torrential flood which reached a depth of 7 feet over the 70 foot crest. Note the tower drag line and the caterpillar dragline in position. When completed the embankment on left was raised ten feet above the wing walls and 25 feet above the spillway crest.

Looking up stream from Garfield Smelter at series of control structures in Kessler Canyon. The tall derrick in the distance is stationed at the site of the main barrier.

Looking down stream across site of main Barrier Spillway Kessler Canyon, during construction.

Lifting Boulders out of the ground for use in building main spillway. Kessler Canyon. These were loaded by drag line crane on to heavy wagons then hauled to site of spillway by tractor.

Boulders being placed by heavy derrick, in foundation of main spillway, Kessler Canyon.

Building an equalizing check above intake to tunnel through Garfield Smelter. Note main tunnel opening in distance, which is same cross-sectional area as opening in foreground.

Constructing a check dam in Kessler Canyon below main structure.

Looking down stream from main spillway, Kessler Canyon. The screen in middle of picture was built to remove floating debris which might clog the tunnel, intake of which is shown in the distance. Railroad yards and Garfield Smelter in background beyond which is great Salt Lake.

Detail of Rubble-Concrete Construction. Arch is 15 ft. high.

Guniting a Rubble-Concrete wing wall - Kessler Canyon

Gasoline driven shovel building the flood barrier, Kessler canyon. This dike was later raised 15 feet by tower dragline.

Spillway through main barrier, Kessler Canyon. This structure is a new departure in spillway construction. It stands 80 feet high and rests upon an alluvial foundation. Huge boulders, some of which weigh two or three tons, were placed in position then grouted together.

The flood stream drops over a circular crest into a stilling pool ten feet deep. A secondary crest below the stilling pool passes the stream quietly into the channel below.

Another view of Kessler Spillway while upper crest was being raised.

Equalizing check just above Rail Road Yards -- Kessler Canyon.

Centerville School after 1930 flood. Steam shovel digging debris away and building a heavy deflector above the building. School

Another view of Centerville School showing embankment above building and shovel at work on same.

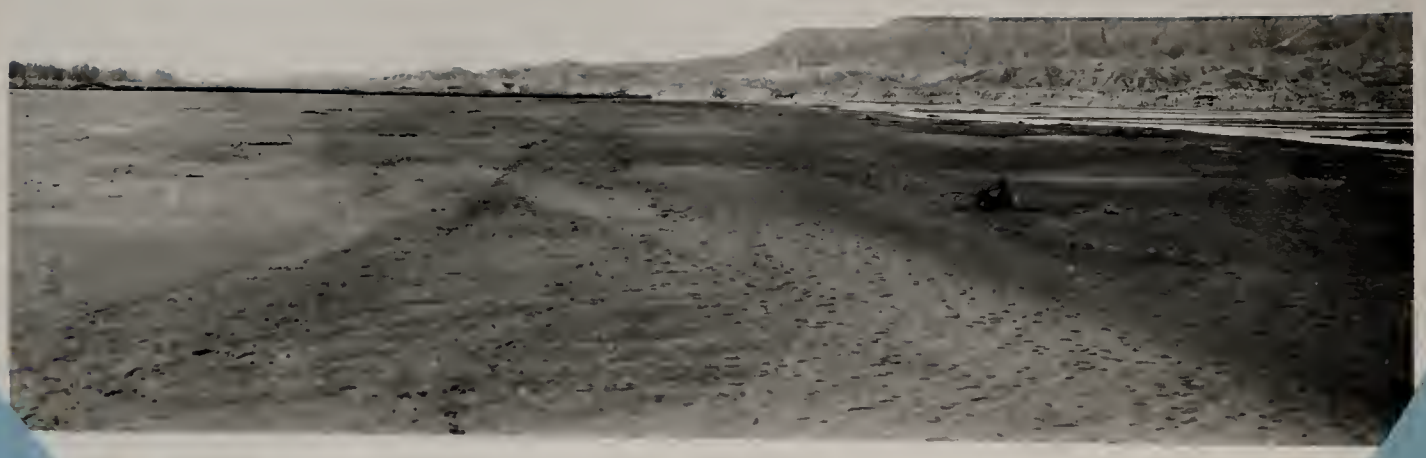
Going home after a hard-day's work on Parrish Creek flood barrier. Rocks brought down by flood used in building a heavy wall along margin of control basin. Note similar wall on left. A cross barrier connects the two lateral walls above the school house in distance.

Diversion Dam on Santa Clara at intake to Clara Bench Canal. This structure is washed out by every freshet. It is proposed to construct a Flood Control Structure near this site which will serve also as a prominent diversion dam.

Mass meeting of water users on site of proposed flood control dam. It was decided at this meeting to build the structure.

Looking down Santa Clara after control work was begun in February, 1933. Horseman in center is riding up the newly constructed channel through which spring high water is flowing. Note condition of erosion on either side.

Flood breaker on Santa Clara Creek built during March, 1933. This is one of a series designed to hold the flood stream within a prescribed channel.



Character of lower Virgin River Flood Channel. Much of the tillable area has been washed away. On the extreme left is the town of Bunkerville, Nevada which is threatened with total distruction. During March and April the community has begun the construction of a series of flood breakers designed to hold the channel within bounds. The first one extends from center of picture to the main land on left, a distance of a thousand feet.

Looking up-stream from site of first breaker. See highway bridge in distance.

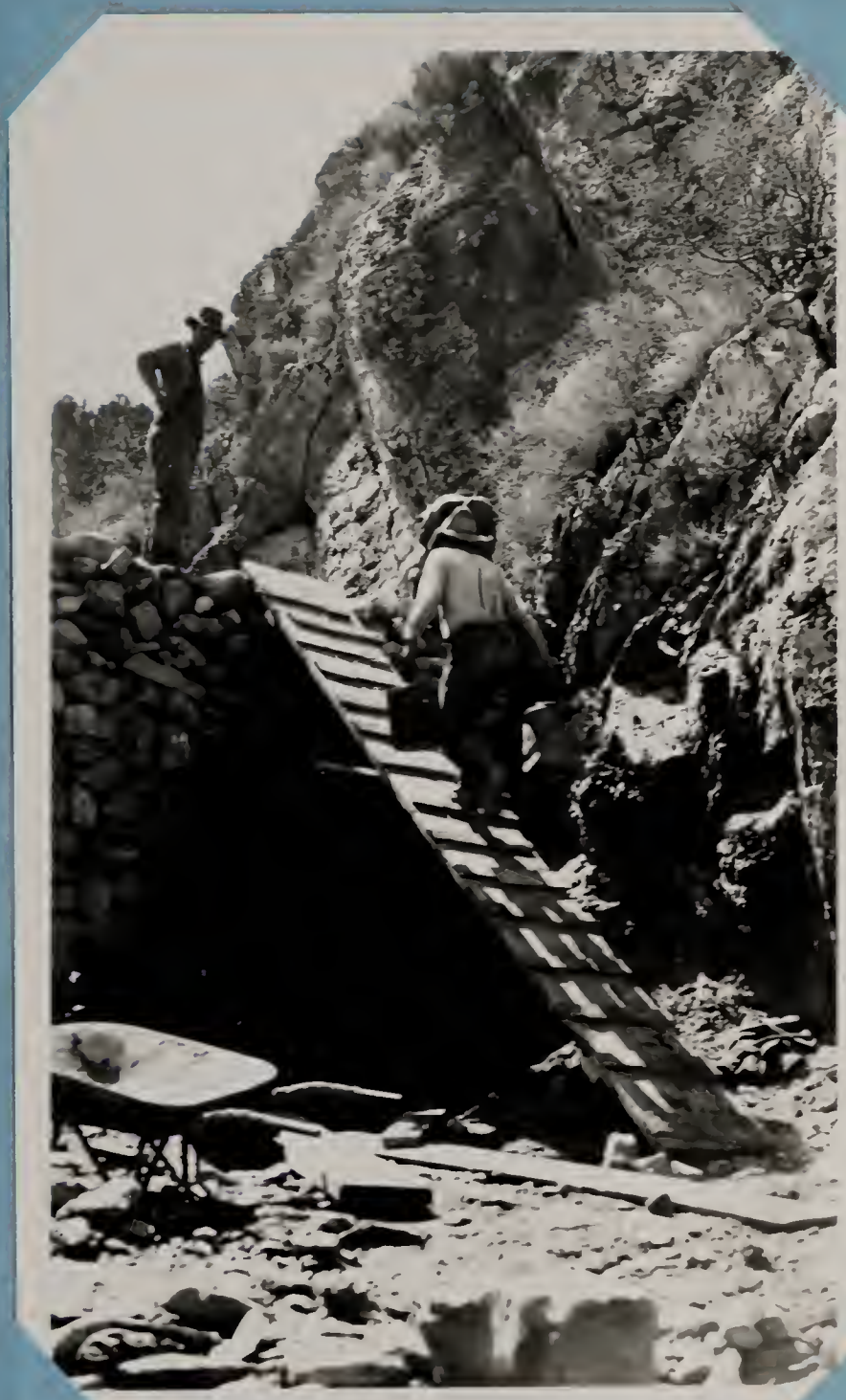
Highway bridge across Virgin River near Mesquite, Nevada. Looking up-stream.

Diversion dam at intake to Bunkerville Canal. This structure must be rebuild after every flood. The structure is 3000 feet long and was rebuilt last time at an expense of $10 per acre for land irrigated.

Character of watershed on portion of Virgin River Drainage Area. Solid sand rock with only an occasional crevace where soil collects sufficient for support of plant life.

Another view of Virgin River watershed.

View showing method of building a high wall of rubble-masonry. Boulders are being carried up gang plank on left and concrete is elevated on right from mixing board to wall in buckets. In this way one sack of cement builds one cubic yard of wall — all hand labor, no waste of materials.



Another view showing workman carrying concrete mortar to top of an 18-foot rubble wall.

View showing mixing board where four laborers mix a one sack batch of concrete at a single mixing.

Beginning of a rubble masonry dam in narrows above Kanarrah, Utah, where flood-waters are to be checked, unburdened of their load of boulders, gravel and sand and delivered for irrigation through a submerged orifice, in a uniform stream of constant volume. Formerly this stream has been only partially used, because of excessive fluctuation and because of enormous loads of debris which filled canals rendering them useless until cleaned.

Flood Control Structure in process of construction at Magna, Utah. This is being built entirely by hand labor as an R.F.C. make work project.

View shows spillway above intake to tunnel beneath Bingham and Garfield Railroad, just south of Magna.